Astrodynamics/History

Astrodynamics

History of Astrodynamics

The study of the sun, moon, and stars has been a subject of prominence among humans for many thousands of years. Because the revolution of the earth and other planets around the sun, and the daily rotation of the earth on its axis create regular patterns of motion, the study of the stars and planets was used as a method to tell time. The location of the north star, polaris, and the constellation "the southern cross" were used by ocean navigators to travel the seas in the times before magnetic compasses. Many religious ceremonies and beliefs also grew around the stars and their constellations.

The study of the motions of the stars and planets has also been a major driving force behind mathematics and science. Some of the fruits of this study are the optical lense (for use in telescopes) and the field of calculus. Many modern inventions and technologies were also furthered because of modern space exploration. It is for all these reasons that we are studying astrodynamics.

Early History

Since ancient times, the heavens have been studied. It was known by the 2nd millennium BC, that certain lights in the night sky did not remain fixed with respect to the background stars. The Ancient Greeks referred to these as *planetes asteres*, "wandering stars" and their motions were studied extensively, even in ancient times. Theories of their motions eventually culminated in the third century with the *Almagest*, written by Claudius Ptolemy. The **Ptolemaic system** placed earth at the center of the universe with seven planets (the moon, Mercury, Venus, the sun, Mars, Jupiter and Saturn) which revolved about the earth on successively larger crystalline spheres which were again bounded by the sphere of fixed stars. Complex motions of the planets were explained via epicycles, which will not be discussed in great depth here. Despite modern understanding of the flaws in the Ptolemaic system, it was fairly accurate and remained the basis of astronomy and cosmology until the 17th century.

The Renaissance

Nickolaus Copernicus, having taken several measurements of the motions of various planets, came to the conclusion that the sun was the center of the universe, and that the earth rotated around the sun. Copernicus' model also assumed that the orbits of the planets were circular, which left a few inconsistencies from his measurements, but the model was much more simplistic then the Ptolemaic model.

Urban myth holds that Copernicus' theory was dismissed by the Catholic Church, when in reality Copernicus' book was funded by a church cardinal, and was dedicated to the current pope. It wasn't for nearly 100 years later, after Kepler had begun publishing that the church denounced the idea as heretical.

150 years after Copernicus, Galileo Galilei began to observe the heavens with a telescope that he constructed; contrary to popular belief, he did not invent the telescope, but he was the first to use it for astronomical purposes. He made several discoveries including the four largest moons of Jupiter, phases of Venus, sunspots, rings of Saturn and the topography of the moon. These discoveries challenged long held notions that the Earth was the center of the universe and that the planets were perfect ethereal spheres.

Galileo also helped lay the groundwork of the concepts of kinematics and inertial coordinate frames, both of which are important foundations of Classical Mechanics.

Johannes Kepler

Tycho Brahe, a Danish nobleman, was a keen observer and machinist, and used his talents to compile a listing of the most accurate observations of stars and planets that had ever been taken up to that point. However, Brahe lacked the intuition to fit that data to a mathematical model. Brahe's assistant, **Johannes Kepler**, an accomplished mathematician was tasked with using the data to compute future positions of the planets.

Following Brahe's death, Kepler inherited the body of data which he used to derive laws to accurately describe the motions of the planets. While Kepler did not understand the physical basis behind his discoveries, his three laws of planetary motion still bear his name today.

Isaac Newton

Isaac Newton, the famous mathematician and physicist, used his new invention calculus to derive the orbital motion of a planet as an ellipse. However, it wasn't until after being prodded by **Edmond Halley**, a fellow scientist, that he was persuaded to publish his work, *Principia Mathematica* with his results.

Halley, Newton's only contemporary that was able to understand the new calculus, was able to use Newtons results to predict the path and the time of return for the comet that still bears his name.

Lagrange and Gauss

Gauss is known as an amazing mathematician, but many of the results he produced were due to his study of astronomy. Gauss developed many of the mathematical tools that we use today to study orbits. One of his developments, *Least Mean Squares* curve fitting, was developed to apply an orbit to a series of inexact measurements, but has since found uses in nearly every branch of engineering, science, and mathematics.

Einstein and Relativity

In the early 20th century, understanding of physics was again revolutionized, this time by Albert Einstein with his Theory of Relativity. The special theory, published in 1905, posits that the speed of light is constant for all inertial frames of reference, which has the effect of unifying the concepts of space and time and also the concepts of mass and energy. The general theory, published in 1917, expanding relativity beyond inertial reference frames describes gravity as a curvature in space-time resulting from the presence of matter and energy. Relativity has withstood numerous tests and experiments and remains one of the pillars of modern physics.

However, in most applications (including astrodynamics), Newtonian physics serves as a sufficient description of the motion of bodies and the effects of relativity can be ignored. Notable exceptions to this are GPS systems with rely on extremely precise time signals and must account for slight time dilation that occurs as a result of relativistic physics. Another notable example from celestial mechanics is the orbit of Mercury, which experiences precessional effects that cannot be explained by classical physics.